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GENETICS OF WITCHWEED (*STRIGA HERMONTHICA* (DEL.) BENTH) RESISTANCE IN SORGHUM (*SORGHUM BICOLOR* (L.) MOENCH)

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ABSTRACT

Study on the genetics of witchweed (Strigahermonthica (Del.) Benth) resistance in sorghum (Sorghum bicolor (L) Moench) was conducted in a randomised complete block design experiment at the Institute for Agricultural Research Samaru, (Northern Guinea Savanna 110 11' N: 70 38' E, 686m) Zaria, Kaduna state, Nigeria. Five sorghum varieties: two Strigaresistant varieties (ICSR94405 and ICSR94407) and three susceptible varieties, (SAMSORG40, SAMSORG14 and SAMSORG17) were used for the study. The study was undertaken to determine the variability for resistance to Strigaand other agronomic traits in sorghum and to determine inheritance of resistance to Strigain sorghum. The resistant varieties used as male parents were crossed to the susceptible parents which were the females and F_1, F_2 and backcross populations were generated. The six populations: P_1, P_2, F_1. F_2, BCP_1, and BCP_2 were evaluated at IAR SamaruStrigasick plot in 2012. The result revealed highly significant difference among the genotypes for the traits studied. The result showed that additive gene action is more important for the inheritance of Strigaresistance in sorghum. Inheritance of resistance to Strigain the F2 populations involving the male parent: ICSR94407 is controlled by two dominant genes which are complementary, while in F2 populations involving *ICSR94405; it is* ***controlled in part by genes at two or more loci.***

Keyword: Witchweed, sorghum, hybrid, genetics, backcross, coefficient of variation, inheritance, resistance.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is a major cereal in the semi-arid tropics of sub-Saharan Africa. It belongs to the family Poaceae, and probably originated from south of the Sahara in Africa. It is an important world crop, used for food, fodder, production of alcoholic and non-alcoholic beverages, as well as biofuels. Some varieties are drought and heat tolerant, and are especially important in arid regions, where the grain is staple or one of the staples for the poor and rural people. It is the "fifth most important cereal crop grown in the world after rice, maize, wheat and barley" (Kuhlman *et al*., 2010). Nigeria's annual production of sorghum was 6.8 million metric tons in 2011 (FAO, 2012) and 6.9 million metric tons in 2012 (FAO, 2013).

However, sorghum production is affected by both biotic and abiotic constraints. One of the major biotic constraints to sorghum production in sub-Sahara Africa is the parasitic flowering weeds of the genus *Striga*. This seriously limits cereal production in sub-Saharan Africa. Two out of three fields cropped with cereals are estimated to be infested by *Strigaspp* (Lagoke*et al*., 1991). Beside withdrawal of water, nutrient and assimilates, *S. hermonthica*damages its host by inducing enzyme and plant hormone changes, disrupting host-water relationships and carbon fixation (Press *et al*. 1996).

Heavy infestations by these notorious hemi parasites have caused farms to be abandoned and at times, migrations of farming communities (Lagoke*et al*., 1991). *Striga*has infested over 40% of arable land in sub-Saharan Africa (SSA) (Lagoke*et al.* 1991) and caused yield losses of up to 100% (Hassan *et al.* 1994). In Nigeria, *Striga*is infesting about 6.5 million hectares (out of 9.32million ha under sorghum), causing an estimated 35% yield loss (amounting to about 3.3million MT of sorghum yield loss annually (Obilana, 2011a). It is imperative that *Striga*populations be controlled so that they remain below the economic threshold.

The recommended control methods of *Striga*infestation include heavy application of nitrogen fertilizer, the use of trap crops and chemical stimulants to abort seed germination, hoeing and hand pulling, herbicide application and the use of resistant or tolerant crop varieties. None of these methods is effective on its own and most farmers have not accepted the methods to a great extent due to technological and socio-economic reasons. Chemical control of *Striga*is expensive and cannot be afforded by resource-poor farmers (Lagoke*et al.*, 1991).

However, Mabasa (1996) indicated that resistant cultivars offer an economically feasible and culturally sustainable technology for smallholder farmers since they can be grown under conditions of erratic rainfall and low soil fertility and do not require additional cost and inputs. *Striga*-resistant cultivars should be a major component of integrated *Striga*control packages, since they effectively reduce *Striga*emergence, and enhance the efficiency of other control measures. Inadequate information on the genetics of *Striga*resistance and the difficulty of evaluating the trait in segregating progenies has limited the transfer of resistance into varieties better adapted to target areas (Vasudeva, 1985: Ejeta*et al*., 1992).

The knowledge of inheritance of resistance to *Striga*, variance components and genotypic performance will therefore be useful in developing *Striga*resistant cultivars or genotypes.

There is therefore a need for solutions to the menace that would ensure satisfactory increase in grain yield without requiring additional investment (Gbehounou and Adengo 2003; Rodenburg*et al*., 2005). Thus, this study was undertaken with the following objectives:

To study the genetics of *Striga*resistance in some sorghum varieties,determine variability for resistance to *Striga*and other agronomic traits in sorghum and determine the mode of inheritance of *Striga*resistance in sorghum

MATERIALS AND METHODS

Description of the study site

The research was conducted at Institute for Agricultural Research (IAR) Farm, Samaru (110 11' N: 70 38' E, 686m) in Northern Guinea Savanna of Nigeria in 2011/2012.

Description of the plant materials

The materials that were used in this study comprised three IAR sorghum varieties: SAMSORG14, SAMSORG17 and SAMSORG40; and two *Striga*resistant varieties from ICRISAT India: ICSR94405 and ICSR94407. The IAR sorghum varieties were obtained from the Institute for Agricultural Research (IAR) Cereal Research Program. These varieties were chosen because they are most commonly grown cultivars by the farmers within the sorghum production zone.

The F_1 hybrids

In 2011 growing season, the parent seeds were sown in order to make crosses between *Striga*resistant varieties (males) and the IAR varieties (females) using factorial mating design. The IAR varieties that were used flowered at variable periods: SAMSORG14, 100 days, SAMSORG17, 110 to 120 days, and SAMSORG40, 80 days; while the *Striga*resistant varieties: ICSR94405 flowers at 70 days and ICSR94407, at 75 days. Staggered sowing of the genotypes was adopted in order to synchronize the flowering and subsequent pollination. There were four plots, designated June plot, and July plots. June plot consist of two plots; SAMSOG17 was sown first on one plot, while SAMSORG14 was sown ten days later on the second plot. The July plots were also two; ICR94405, ICR94407 and SMSORG 40 were sown on the same day on one plot; and five days later ICSR94405 and ICSR94407 were sown again on the second plot. All genotypes were sown in plots consisting of 10 rows of 5meters long, with spacing of 75cm between rows and 30cm between plants. All the agronomic practices which include thinning, weeding, fertilizer application and earthen up were observed. In the June plot, SAMSORG14 and SAMSORG17 used as female were hand pollinated with ICSR94405 and ICSR94407 as male. In the July plots SMSORG40 used as female was hand pollinated with ICSR94405 and ICSR94407 as male and all the genotypes were also selfed. Hand emasculation was also done to remove the anthers in order to prevent self-fertilization. The seeds were hand harvested and seeds from each cross and the selfed parents were threshed separately and kept in clearly labelled bags.

The F_2 populations

In 2012 dry season (January to June), the F_1 hybrids developed from crosses in 2011, together with their parental lines were sown in the IAR Samaru irrigation field. All the recommended agronomic practices were observed. At heading, the F_1 panicles in every cross were covered with paper bag to ensure complete selfing. Seeds from the selfed plants in each cross were harvested threshed and kept in clearly labelled bags as F_2 s.

The Backcross

From the same plots that were used to produce F_2s seeds, before anthesis, the F_1 plant's heads were covered with paper bags to collect pollen. However, the parental lines were emasculated at anthesis. Then the F_1 of each cross was backcrossed to their respective parents to generate $BCP_1$and BCP_2, (given twelve backcross populations); and this was done by hand pollination. At maturity, seeds developed from the plants were harvested and kept in labelled bags as backcross seeds.

Evaluation of Genetic populations

The parentals, F_1s, F_2s and backcross populations (twenty nine genotypes) were sown in 2012 planting season at the IAR Samaru*Striga*sick plot.

The experiment was carried out using Randomized Complete Block Design (RCBD), with three replications. There were six treatments representing plant populations by a given cross: P_1, P_2, F_1, F_2, BCP_1 and BCP_2. Plot size for non-segregating populations (P_1, P_2, and F_1) was 2 rows of 4m length and 75cm apart. And that of the segregating populations (F_2, BCP_1 and BCP_2) was 5 rows of 4m length and 75cm apart. The intra-row spacing was 30cm in every plot. The plots were inoculated with *Striga*during sowing by putting 10ml of *Striga*mixed with fine sand in the hole where the sorghum seeds were sown. Recommended agronomic practices were observed.

Data collection.

Data were collected on the following;

- Germination percentage: percentage of sorghum plants that germinated after two weeks of sowing.
- Days to 50% heading – days taken from sowing to when 50% of the plants in a plot had completed heading.
- Plant height – distance in centimeter from soil surface to tip of panicle at maturity.
- Panicle length – the distance in centimeter between inflorescence base to its tip at maturity.
- Panicle weight – the weight in grams of un-threshed single panicle after harvesting.
- Grain yield per plant – Grains separated from the panicle of each plant were weighed and the weight of the grains recorded and expressed in grams.
- 1000 grain weight – the weight in grams of 1000 randomly selected grains from individual plant.
- *Striga*count per plant at 12 weeks after sowing - the number of *Striga*that emerged on each plant at 12 weeks after sowing was recorded.
- *Striga*damage score – crop syndrome rating which reflect the damage caused to the host plant in reaction to *Striga*infestation was recorded. This was done using a scale of 0 to 9 rating (Sinebo and Drennan 2001).

Statistical analysis

The data was subjected to analysis of variance using generalized linear model procedure of SAS package (SAS, 2009). Analysis of variance (ANOVA) model for RCBD is

$y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}$ and i = 1…..a, j = 1…..b

Where:

y_{ij}= An observation in treatment i and block jμ = The overall mean α_i =The effect of treatment β_j = The effect of block j e_{ij} = Random error with mean 0 and variance σ^2 α = The number of treatments; b = The number of blocks

Coefficient of variation

The coefficient of variation was calculated to measure the relative variability of given populations. Variance estimates have units attached to them. A common application of variance is the test to find out if one biological sample is more variable for one trait than for another. The coefficient of variation facilitates the comparison because it is unit free. The coefficient of variation (CV) is calculated as:

$$CV = \left({S}/{\bar{X}}\right) x \ 100$$

where: S = Standard deviation, and $\bar{X}$ = mean.

Chi-square test

A chi-square test was conducted to test the goodness of fit of the F2 population of the six crosses involving the resistant and susceptible parents, into the following segregation ratios: 3:1, 9:7, and 13:3 using the formula by (Little and Hill, 1978).

$$\chi^2 = \sum \frac{(O-E)^2}{E} \text{ At (n - 1) df.}$$

Where:

χ^2= chi-square value, O = Observed value, E = Expected value, n = Number of classes, df = Degrees of freedom and $\sum$ = summation.

Deviations were taken as non-significant wherever the calculated χ^2 value is less than the table value at 5% level of significance and the ratio presumed was taken as showing good fit.

RESULTS

Analysis of variance

The analysis of variance showed significant differences among the genotypes ($P < 0.01$) for all the traits measured. However, Mean squares for replication were not significant for all the traits measured (Table 1).

Table 1: Mean square for eight agronomic traits of sorghum grown in Samaru in 2012

Source of variation	Df	GP	HD	PH	GY/Plt	1000GW	PaL	SDS	SC
Rep	2	15.53	0.84	0.56	0.42	1.42	0.54	0.92	0.05
Genotype	28	233.78**	113.03**	1813.86**	331.73**	55.51**	40.35**	27.26**	3.69**
Error	56	14.03	0.63	0.59	0.18	4.92	0.63	0.41	0.05

** Highly significant at 1 percent level of significant, GP: Germination percentage, HD: Days to 50% heading, PH: Plant height, GY/Plt: Grain yield per plant, 1000GW: 1000 grain weight, PaL: Panicle length, SDS: *Striga*damage score, SC: *Striga*count per plant.

Means, ranges and coefficient of variation

The performances of various generations of the six crosses involving two *Striga*resistant parents and three IAR released varieties are presented in Table 2 below.

Plant height.

For the cross between SAMSORG14 and ICSR94405(SAMSORG14 x ICSR94405), the resistant parent, ICSR94405 had a mean height of 170.20cm and a range between 145cm and 200cm. SAMSORG14 had a mean of 200.70cm with a range between 157cm and 260cm. The F_1 hybrid had a mean of 188.47cm with a range between 180 and 263cm. The F_1 mean was a bit higher than the mid-parent (185.45). There was high level of segregation among the F_2 population with the range of the F_2 being outside the parental range (139 – 304) couple with the CV of 28.36% and mean height of 210.11cm. Mean Plant height for the backcrosses, BCP_1 and BCP_2 were 173.94 and 207.29, respectively.

In the second cross: SAMSORG17 x ICSR94405, SAMSORG17 had a mean plant height of 180.00cm. The F_1 generation from this cross had a mean plant height of 179.87cm, higher than the mid-parental value (175.10cm). F_2 population had a range from 136cm to 231cm with mean of 184.81cm and CV of 15.95%. The $BCP_1$and BCP_2 had mean values of 170.50cm and 184.56cm, respectively.

In the cross between SAMSORG40 x ICSR94405, SAMSORG40 had a mean plant height of 156.33cm, with the range of 137cm -167cm. The F_1 mean was 167.00cm higher than the mid-parental mean (163.26cm), and the F_2 ranges from 130cm - 210cm with mean plant height of 170.67cm and CV of 12.93%. The BCP_1 and BCP_2 had mean values of 160.50cm and 161.56cm, respectively.

In crosses involving ICSR94407 as the resistant parent, ICSR94407 had a mean plant height of 155.73cm.The F_1 hybrid of SAMSORG14 x ICSR94407 had a mean height of 180.5cm. The F_2 population had a mean height of 204.64cm with a range of (135-281cm) and CV of 23.42%. Mean Plant height for the backcrosses BCP_1 and BCP_2 were 160.31cm and 217.82cm, respectively.

In the second cross: SAMSORG17 x ICSR94407, the F_1 hybrids had a mean plant height of 170.13cm, the F_2 population had a range from 127cm to 225cm with mean of 166.68cm and CV of 12.67%. The $BCP_1$and BCP_2 had mean values of 157.08cm and 176.59cm, respectively.

In SAMSORG40 x ICSR94407, the mean height of the F_1s was 157.57cm, similar to the mid parent mean (156.03cm). The F_2 had a mean height of 170.67cm with a range of 130cm to 210cm and CV of 14.82%. The $BCP_1$and BCP_2 had mean height of 157.08cm and 176.59cm, respectively.

Panicle length.

In all the crosses, the mean panicle lengths of the susceptible parents are higher than that of the resistant parent. The mean panicle length for the susceptible parents varied from 27.77cm for SAMSORG40 to 30.35cm for SAMSORG14. Those of the resistant parents were 20.96 and 22.82 for ICSR94405 and ICSR94407, respectively. Mean Panicle length of the F1 hybrids in the first cross (SAMSORG14 x ICSR94405) was 34.25cm, higher than the mid parent mean (25.66cm). The F_2 population had mean panicle length of 33.76cm, range from 24cm to 40cm and CV of 13.01%. The backcrosses, BCP_1 and BCP_2 had mean panicle length of 25.98cm and 29.04cm, respectively.

In SAMSORG17 x ICSR94405, the F_1 had mean panicle length of 27.02cm; the F_2 had mean panicle length of 24.15cm, range from 19cm to 39cm and CV of 15.84%. BCP_1 and BCP_2 had mean panicle length of 23.09cm and 31.32cm, respectively. F_1 (SAMSORG40 x ICSR94405) recorded mean panicle length of 25.59cm; the F_2 had mean panicle length of 26.12cm, range of 19cm-31cm and CV of 10.98%. The BCP_1 and BCP_2 population recorded mean panicle length of 22.69cm and 27.98cm, respectively. For the crosses involving ICSR94407, the resistant parent ICSR94407 had mean panicle length of 22.82cm. The F_1 (SAMSORG14 x ICSR94407) recorded mean panicle length of 34.19cm a bit higher than the mid parent mean (26.59cm). The F_2 had mean panicle length of 31.10cm, range of 25cm-44cm and CV of 14.68%. BCP_1 and BCP_2 had mean panicle length of 23.99cm and 31.34cm, respectively.

In the cross between SAMSORG17 and ICSR94407, the F_1 had mean panicle length of 28.42. The F_2 had mean of 27.28cm, range of 22cm-38cm and CV of 18.35%. BCP_1 and BCP_2 had mean value of 23.23cm and 29.75cm, respectively.

In SAMSORG40 x ICSR94407, the F_1 had mean panicle length value of 26.43cm. F_2 population had mean panicle length of 23.92cm, range of 19cm-36cm and CV of 14.48%. The BCP_1 and BCP_2 recorded mean panicle length of 24.63cm and 27.21cm, respectively.

Panicle weight.

Mean values for panicle weight varied from 82.62g (SAMSORG40) to 118.09g (SAMSORG17), then 76.43g and 81.90g for ICSR94405 and ICSR94407 respectively. In the six crosses, the mean values for the F_1 hybrids varied from 80.77g (SAMSORG40 x ICSR94405) to 107.23g (SAMSORG17 x ICSR94407). The F_2 population had a wide range of segregation. The mean panicle weight for the F_2 population in the six crosses varied from 83.35g (SAMSORG40 x ICSR94405) to 121.31g (SAMSORG17 x ICSR94407), the CV range from 18.67% (SAMSORG17 x ICSR94407) to 40.74% (SAMSORG14 x ICSR94405). Mean panicle weight for BCP_1varied from 78.32g [ICSR94407 x (SAMSORG40 x ICSR94407)] to 85.92g [ICSR94407 x (SAMSORG17 x ICSR94407)] and that of BCP_2 varies from 80.19g [SAMSORG40 x (SAMSORG40 x ICSR94407)] to 120.26g [SAMSORG17 x (SAMSORG17 x ICSR94407)].

Table 2: Range, mean and CV of plant height, panicle length and panicle weight of the parents, F_1, F_2 and backcross populations of six sorghum crosses evaluated under Strigainfestation at IAR SamaruStrigasick plot in 2012.

Generation/Cross	Plant height (cm)			Panicle length (cm)			Panicle weight/plant (g)		
	Range	Mean	CV	Range	Mean	CV	Range	Mean	CV
SAMSORG14 x ICSR94405									
ICSR94405	145-200	170.20	10.89	19-27	20.96	8.69	50-108	76.43	10.25
SAMSORG14	157-260	200.70	10.98	25-36	30.35	9.22	60-120	113.03	12.96
F_1	180 – 263	188.47	11.29	28-44	34.25	11.48	88-112	100.52	16.44
F_2	139 -304	210.11	28.36	24-40	33.76	13.01	78-126	103.19	40.74
BCP_1	130 -220	173.94	28.32	20-34	25.98	10.30	45-111	87.40	40.87
BCP_2	143 – 242	207.29	16.47	25-37	29.04	11.63	48-124	118.64	28.52
Table 2 Continued.									
Generation/Cross	Plant height (cm)			Panicle length (cm)			Panicle weight/plant (g)		
	Range	Mean	CV	Range	Mean	CV	Range	Mean	CV
SAMSORG 17XICSR94405									
ICSR94405	145 – 200	170.20	10.89	19-27	20.96	8.69	50-108	76.43	10.25
SAMSORG17	140 – 190	180.00	8.26	22-36	29.07	8.04	79-129	118.09	10.91
F_1	150 – 246	179.87	10.60	25-31	27.02	6.21	71-125	100.75	15.28
F_2	136 – 231	184.81	15.95	19-39	24.15	15.84	42-131	105.21	25.48
BCP_1	120 – 221	170.50	13.89	18-31	23.09	11.99	44-108	79.56	22.66
BCP_2	130 – 218	184.56	13.73	21-38	31.32	12.97	63-112	110.45	23.72
SAMSORG40 x ICSR94405									
ICSR94405	145 – 200	170.20	10.89	19-27	20.96	8.69	50-108	76.43	10.25
SAMSORG40	137 – 167	156.33	6.62	24-32	27.77	7.14	57-111	82.62	12.26
F_1	155 – 180	167.00	4.20	21-29	25.59	8.82	61-117	80.77	15.51
F_2	130 – 210	170.67	12.93	19-31	26.12	10.98	36-123	83.35	23.89
BCP_1	121 -231	160.50	14.11	19-29	22.69	9.82	35-117	79.31	20.33
BCP_2	127 – 208	161.56	12.63	21-32	27.98	10.10	33-102	80.19	21.92
SAMSORG14 x ICSR94407									
ICSR94407	140 – 170	155.73	6.11	20-27	22.82	8.97	60-95	81.90	10.25
SAMSORG14	157 – 260	200.70	10.98	25-36	30.35	9.22	60-120	113.03	12.96
F_1	167 – 221	180.50	13.58	25-40	34.19	11.65	84-130	102.30	13.74
F_2	135 – 281	204.64	23.42	25-44	31.10	14.68	53-134	119.95	35.66
BCP_1	120 – 231	160.31	22.91	19-30	23.99	11.82	30-115	82.85	33.41
BCP_2	155 – 271	217.82	11.75	22-39	31.34	11.42	87-124	112.26	16.68
SAMSORG17 x ICSR94407									
ICSR94407	140 -170	155.73	6.11	20-27	22.82	8.97	60-95	81.90	10.25
SAMSORG17	140 -190	180.00	8.26	22-36	29.07	8.04	79-129	118.09	10.91
F_1	150 - 180	170.13	8.48	22-34	28.42	10.82	86-133	107.23	11.94
F_2	127 - 215	166.68	12.67	22-38	27.28	18.35	57-135	121.31	18.67
BCP_1	136 - 190	157.08	6.48	19-29	23.23	14.14	58-109	85.92	15.46
BCP_2	147 - 209	176 59	8.52	26-34	29.75	16.29	61-115	120.15	14.42
SAMSORG40 x ICSR94407									
ICSR94407	140 - 170	155.73	6.11	20-27	22.82	8.97	60-95	81.90	10.25
SAMSORG40	137 - 167	156.33	6.62	24-32	27.77	7.14	57-111	82.62	12.26
F_1	140 - 167	157.57	5.19	20-30	26.43	10.32	60-104	84.84	11.64
F_2	130 - 210	170.67	14.82	19-36	23.92	14.48	42-114	88.80	20.71
BCP_1	122 - 195	160.21	10.98	21-32	24.63	12.11	46-103	78.32	18.74
BCP_2	125 - 185	161.94	10.67	24-34	27.21	11.90	49-96	80.10	18.57

Grain yield

As shown in table 3, mean values for grain yield per plant, ranges from 75.73g (SAMSORG40) to 110.93g (SAMSORG17) and 67.97g (ICSR94405) to 78.33cm (ICSR94407). The F_1 means ranges from 73.40g (SAMSORG40 x ICSR94405) to 96.10g (SAMSORG17 x ICSR94407) in all the crosses. F_2 means for grain yield per plant ranges from 77.84g (SAMSORG40 x ICSR94407) to 117.29g (SAMSORG17 x ICSR94407). The CV varied from 12.74% (SAMSORG40 x ICSR94407) to 28.55% (SAMSORG14 x ICSR94405). There were high ranges of segregation among the F_2 populations as shown in the CV. Mean grain yield per plant for BCP_1 in all the crosses varied from 73.65g [ICSR94405 x (SAMSORG17 x ICSR94407)] to 84.73g [ICSR94407 x (SAMSORG14 x ICSR94407)], while that of BCP_2 varied from 76.44g [SAMSORG40 x (SAMSORG40 x ICSR94407)] to 110.33g [SAMSORG17 x (SAMSORG17 x ICSR94407)].

Grain weight (1000)

SAMSORG14, SMSORG17 and SAMSORG40 had mean values of 34.04g, 39.35g and 27.71g with range of 30g - 36g, 38g – 42g and 27g -30g and CV of 6.64%, 3.29% and 6.12%, respectively, while the resistant parents had mean values of 22.48g and 21.83g with range of 20 – 27g and 20g - 24g and CV of 7.62% and 5.54% for ICSR94405 and ICSR94407 respectively. In the cross between SAMSORG14 and ICSR94405 the F_1 means was 30.62g, with the range of 30g -34g and CV of 4.28%. The F_2 had a mean of 28.14g, with range of 20g – 30g and CV of 13.47. Mean, range and CV for BCP_1 in the same cross were: 25.71g, 23g-29g and 9.77%, respectively and BCP_2 had mean, range and CV of 38.01g, 35g – 41g and 11.41%, respectively.

For the second cross; SAMSORG17 x ICSR94405, the F_1 had the mean 1000 grain weight of 32.03g, with range of 29g – 36g and CV of 8.06%. The F_2 recorded mean 1000 grain weight of 30.31g, range of 21g – 37g and CV of 13.74%. BC_1P_1 mean was 22.67g with CV of 12.67% and range of 21g-26g, while BC_1P_2 of the same cross had mean of 34.45g, CV of 10.10% and range of 20g – 38g. Cross between SAMSORG40 and ICSR94405 had F_1 mean, range, and CV values for the trait to be 27.68g, 26g – 32g and 8.85%, respectively and the F_2 mean was 25.67g, with the range of 25g-37g and CV of 15.96%. Also the BCP_1 mean, range and CV of the trait were 24.99g, 22g-29g and 10.74%, respectively. BCP_2 of the same cross had mean, range and CV of 26.35g, 24g – 32g and 12.61%, respectively.

Cross of SAMSORG14 and ICSR94407 had F_1 mean, range and CV values for 1000 grain weight to be 29.01g, 32g – 35g and 9.62%. The F_2 mean was 29.34g, with range of 27g – 38g and CV of 16.45%. BCP_1 had mean, range and CV of 25.66g, 26g-31g and 11.17%, respectively and BCP_2 of the same cross had mean, range and CV of 30.69g, 29g – 34g and 13.16%, respectively.

For SAMSORG17 X ICSR94407 cross, the F_1 mean was 31.28g with the range of 31g – 34g and CV of 2.24%. The F_2 had mean, range and CV of 26.35g, 23g – 29g and 10.02%, respectively. BCP_1 mean for the trait was 22.70g with CV of 9.37% and range of 21g - 27g and BCP_2 of the same cross had mean of 35.35g, CV of 6.54% and range of 28g – 39g.

SAMSORG40 x ICSR94407 had F_1 mean, ranges and CV values for the same trait to be 26.96g, 26g – 30g and 5.83%. The F_2 mean was 24.67g, with range of 22g – 29g and CV of 10.18%. BCP_1 mean was 25.97g with CV of 8.53% and range of 23g-30g and BCP_2 of the same cross had mean of 30.02g, CV of 9.54 and range of 26g – 33g.

Striga count.

In the six crosses, ICSR94405 and ICSR94407 were resistant, with mean *Striga*count value: 0.03 for ICSR94405 (only one *Striga*emerged) and 0 for ICSR94407 (no *Striga*emergence). Meanwhile SAMSORG14 and SAMSORG40 were susceptible to *Striga,* with mean *Sriga*count value of 3.13 and 4.53 and the range of 2-6 and 2-7 respectively. SAMSORG17 was tolerant with mean *Striga*count of 1.13, range of 0 – 4 and CV of 6.51%. The F_1 of the cross between SAMSORG14 and ICSR94405 had a mean *Striga*count value of 0.97, range of 0-3 and CV of 9.12%. The F_2 had a mean of 1.18, range of 0-5 and CV of 24.20%. BCP_1 of the same cross had mean value of 0.39, range of 0-4 and CV of 16.34%, while the BCP_2 had mean of 2.05, range of 0-5 and CV of 13.40%.

In the cross between SAMSORG17 x ICSR94405, the F_1 had mean *Striga*count value of 0.70, range of 0-3 and CV of 11.34%. The F_2 had a mean of 1.03 and range of 0-5 and CV of 24.10%. BCP_1 of the same cross had mean value of 0.62, range of 0-3 and CV of 16.23%., while the BC_1P_2 had mean *Striga*count of 1.13, range of 0-4 and CV of 12.56%.

The cross of SAMSORG40 x ICSR94405 had F_1 mean *Striga*count value of 1.06, with the range of 0-3 and CV of 9.42%. The F_2 had a mean of 1.17 with the range of 0-5 and CV of 18.73%. BCP_1 of the same cross had mean value of 0.30, with range of 0-4 and CV of 12.33%, while the BCP_2 had mean of 3.75, range of 0-5 and CV of 10.62%.

In the cross between SAMSORG14 x ICSR94407, the F_1 had mean *Striga*count value of 0.90 with range of 0-3 and CV of 10.44%. The F_2 h

2 0.36, with range of 0-3 and CV of 15.30%, while the BCP_2 had mean of 1.92, range of 0-5 and CV of 16.18%.

The cross of SAMSORG17 x ICSR94407 had F_1 mean *Striga*count value of 0.63, with the range of 0-3 and CV of 11.71%. The F_2 had a mean of 0.99, range of 0-5 and CV of 21.33%. BCP_1 of the same cross had mean value of 0.60, with range of 0-3 and CV of 16.61% while the BCP_2 had mean of 1.12, with range of 0-4 and CV of 14.21%.

Finally, in the cross between SAMSORG40 x ICSR94407, the F_1 had mean *Striga*count value of 1.00, with range of 0-3 and CV of 9.50%. The F_2 had a mean of 1.16 with range of 0-5 and CV of 19.43%. BCP_1 of the same cross had mean value of 0.29, range of 0-4 and CV of 13.94%, while the BCP_2 had mean of 3.01, range of 0-5 and CV of 11.41%.

Table 3.Range, mean and CV of grain yield/ plant, 1000 grain weight and Striga count of the parents, F1, F2 and backcross populations of six sorghum crosses evaluated under Striga infestation at IAR SamaruStriga sick plot in 2012.

Generation/Crosses	Grain yield/plant (g)			1000 Grain weight (g)			*Striga*count/plt		
	Range	Mean	CV	Range	Mean	CV	Range	Mean	**CV**
SAMSORG14 x ICSR94405									
ICSR94405	45 – 100	70.97	11.85	20-27	22.48	7.62	0-1	0.03	-
SAMSORG14	54 – 111	102.1	9.34	30-36	34.04	6.64	2-6	3.13	6.51
F_1	78 – 101	91.47	10.39	30-34	30.62	4.28	0-3	0.97	9.12
F_2	65 – 113	94.77	28.55	20-30	28.14	13.47	0-5	1.18	24.20
BCP_1	40 – 107	78.75	27.55	23-29	25.71	9.77	0-4	0.39	16.34
BCP_2	42 – 118	108.78	17.90	35-41	38.01	11.41	0-5	2.05	13.40
SAMSORG17 x ICSR94405									
ICSR94405	45 – 100	70.97	11.85	20-27	22.48	7.62	0-1	0.03	-
SAMSORG17	68 – 120	110.93	8.94	38-42	39.35	3.29	0-4	1.13	6.56
F_1	62 – 114	93.80	11.04	29-36	32.03	8.06	0-3	0.70	11.34
F_2	37 – 120	97.36	14.96	21-37	30.31	13.74	0-5	1.03	24.10
BCP_1	36 – 94	73.65	12.07	21-26	22.67	12.67	0-3	0.62	16.23
BCP_2	43 – 122	112.13	13.97	20-38	34.45	10.10	0-4	1.13	12.56
SAMSORG40 x ICSR94405									
ICSR94405	45 – 100	70.97	8.85	20-27	22.48	7.62	0-1	0.03	-
SAMSORG40	50 – 105	75.73	6.67	27-30	27.71	6.12	2-7	4.53	7.30
F_1	55 – 107	73.40	4.31	26-32	27.68	8.85	0-3	1.06	9.42
F_2	31 – 117	78.59	14.83	25-37	25.67	15.96	0-5	1.17	18.73
BCP_1	37 – 92	69.49	12.47	22-29	24.99	10.74	0-4	0.30	12.33
BCP_2	43-107	75.85	13.11	24-32	26.35	12.61	0-5	3.75	10.62

Table 3 continued

Generation/Crosses	**Grain yield/plant (g)**			**1000 Grain weight (g)**			***Striga*count/plt**		
	Range	**Mean**	**CV**	**Range**	**Mean**	**CV**	**Range**	**Mean**	**CV**
SAMSORG14 x ICSR94407									
ICSR94407	53 – 82	78.33	5.55	20-24	23.83	5.54	0	0.00	-
SAMSORG14	54 – 111	102.10	9.34	30-36	34.04	6.64	2-6	3.13	6.51
F_1	80 – 124	91.40	4.23	32-35	29.01	9.62	0-3	0.90	10.44
F_2	49 -128	108.93	23.24	27-38	29.34	16.45	0-4	1.25	25.11
BCP_1	27 – 110	84.73	22.89	26-31	25.66	11.17	0-3	0.36	15.30
BCP_2	80 – 118	99.82	11.67	29-34	30.69	13.16	0-5	2.92	16.18
SAMSORG17 x ICSR94407									
ICSR94407	53 – 82	78.33	5.55	20-24	23.83	5.54	0	0.00	-
SAMSORG17	68 – 120	110.93	8.94	38-42	39.35	3.29	0-4	1.13	6.56
F_1	79 -126	96.10	6.23	31-34	31.28	2.24	0-3	0.63	11.71
F_2	53 – 129	117.29	18.91	23-29	26.35	10.02	0-4	0.99	21.33
BCP_1	53 – 98	80.63	16.67	21-27	22.70	9.37	0-3	0.60	16.61
BCP_2	55 – 106	110.33	10.05	28-39	35.35	6.54	0-4	1.22	14.21
SAMSORG40 x ICSR94407									
ICSR94407	53 – 82	78.33	5.55	20-24	23.83	5.54	0	0.00	-
ICSR94407	50 – 105	75.73	6.67	27-30	27.71	2.14	2-7	4.53	7.30
F_1	54 – 98	79.87	5.51	26-30	26.96	5.83	0-3	1.00	9.50
F_2	34 – 105	77.84	12.74	22-29	24.67	10.18	0-5	1.16	19.43
BCP_1	36 – 99	78.71	11.23	23-30	25.97	8.53	0-4	0.29	13.94
BCP_2	32 – 85	76.44	10.56	26-33	30.02	9.54	0-6	3.01	11.41

CV = Coefficient of Variation

Segregation Ratios and Chi-square for Striga Damage Score.

Table 5 shows mean *Striga* damage score, range and segregation in F_2 and backcross populations. Plants with scores of 0 to 4 were considered resistant, while plants with score 5 to 9 were considered susceptible (Sinebo and Drennan, 2001). The female parents had mean damage score of 6.6, 5.3, and 6.4, and range of 5-9, 5-6, and 5-8 for SAMSORG14, SAMSORG17 and SAMSORG40, respectively, while the mean damage score for the male parents were 1.2 and 0.9 with range of 0-3, and 0-2 for ICSR94405 and ICSR94407, respectively. The F_1 populations had the following means: 1.4, 1.1, 1.3, 1.3, 0.8, and 1.0 for SAMSORG14 x ICSR94405, SAMSORG17 x ICSR94405, SAMSORG40 x ICSR94405, SAMSORG14 x ICSR94407, SAMSORG17 x ICSR94407 and SAMSORG40 x ICSR94407, respectively. In the F_2 population the chi-square values at expected segregation ratio 3:1 (resistant: susceptible) are significant in all the crosses. The expected ratio 9:7 is significant in F_2 of three crosses involving the resistant parent: ICSR94405 but not significant in the three crosses involving the resistant parent: ICSR94407. Similarly significant chi-square values were obtained in three crosses involving ICSR94407 at the expected segregation ratio 13:3, while the F_2 of three crosses involving ICSR94405 were not significant.

Table 4 continued.

Cross	Parent and Progeny	Mean SDS and Range	Observed		Total	Expected Ratio	χ^2	df	P(0.05)
			R	**S**					
ICSR94407X SAMSORG14	P_1(ICSR94407)	0.9 (0-2)	30	0	30	1:0			
	P_2(SAMSORG14)	6.6 (5-9)	30	0	30	0:1			
	F_1	1.3 (0-3)	30	0	30	1:0			
	F_2	2.5 (0-9)	93	57	150	9:7	2.19	1	0.14^{NS}
	BCP_1	1.4 (0-4)	150	0	150	16:0			
	BCP_2	2.4 (0-9)	77	73	150	1:1	0.11	1	0.74^{NS}
ICSR94407 X SAMSORG17	P_1 (ICSR94407)	0.9 (0-2)	30	0	30	1:0			
	P_2(SAMSORG17)	5.3 (5-6)	30	0	30	0:1			
	F_1	0.8 (0-2)	30	0	30	1:0			
	F_2	2.3 (0-6)	94	56	150	9:7	2.71	1	0.10^{NS}
	BCP_1	1.0 (0-4)	150	0	150	16:0			
	BCP2	2.5 (0-9)	75	75	150	1:1	0.00	1	1.00^{NS}
ICSR94407 X SAMSORG40	P_1 (ICSR94407)	0.9 (0-2)	30	0	30	1:0			
	P_2(SAMSORG40)	6.4 (5-8)	30	0	30	0:1			
	F_1	1.0 (0-4)	30	0	30	1:0			
	F_2	2.4 (0-8)	95	55	150	9:7	3.27	1	3.27^{NS}
	BCP_1	1.2 (0-4)	150	0	150	16:0			
	BCP_2	2.2 (0-8)	79	71	150	1:1	0.43	1	0.51^{NS}

-* Highly significant at 1% level of significant, * Significant at 5% level of significant, R = resistant
S = susceptible

Table 4: mean *Striga* damage score, range and segregation ratio for *Striga* resistance among parents and their F1, F2 and backcrosses

	Parent and Progeny	Mean SDS and Range	Observed R	S	Total	Expected Ratio	χ^2	Df	P(0.05)
ICSR94405 X SAMSORG14	P_1 (ICSR94405)	1.2 (0-3)	30	0	30	1:0			
	P_2(SAMSORG14)	6.6 (5-9)	0	30	30	0:1			
	F_1	1.4 (0-4)	30	0	30	1:0			
	F_2	2.1 (0-9)	126	24	150	13:3	0.88	1	0.35^{NS}
	BCP_1	1.5 (0-4)	150	0	150	16:0			
	BCP_2	2.0 (0-9)	112	38	150	3:1	0.01	1	0.92^{NS}
ICSR94405 X SAMSORG17	P_1(ICSR94405)	1.2 (0-3)	30	0	30	1:0			
	P_2(SAMSORG17)	5.3 (5-6)	0	30	30	0:1			
	F_1	1.1 (0-3)	30	0	30	1:0			
	F_2	1.6 (0-7)	130	20	150	13:3	3.13	1	0.08^{NS}
	BCP_1	1.3 (0-4)	150	0	150	16:0			
	BCP_2	1.6 (0-9)	115	35	150	3:1	0.22	1	0.64^{NS}
ICSR94405 X SAMSORG40	P_1 (ICSR94405)	1.2 (0-3)	30	0	30	1:0			
	P_2(SAMSORG40)	6.4 (5-8)	0	30	30	0:1			
	F_1	1.3 (0-4)	30	0	30	1:0			
	F_2	1.5 (0-4)	115	35	150	13:3	1.83	1	0.18^{NS}
	BCP_1	2.9 (0-8)	150	0	150	16:0			
	BCP_2	2.7 (0-9)	109	41	150	3:1	0.44	1	0.51^{NS}

DISCUSSION

Analysis of Variance

In the present study, the mean square values of all the characters studied were highly significant among the genotypes, indicating that there are variations among the genotypes for all the characters.

Mean, Range and Coefficient of Variation

The susceptible parent (SAMSORG14) had the highest mean plant height value of 200.70cm while resistant parent (ICSR94407) had the lowest mean plant height value of 155.73cm. The mean plant heights for the F_1 hybrid in the entire cross were similar to the mid parental value. This indicated the preponderance of additive gene action for plant height. The height of F_2 plants were distributed over the range of both parents with continuous distribution, suggesting the involvement of more than one gene controlling the inheritance of the trait and it also suggests that gene controlling the trait, are dispersed among the parents. Also from the result, the mean plant heights for the backcrosses (BCP_1 and BCP_2) skewed towards their respective recurrent parents. Mean values of the F_1 hybrids in the six crosses, for panicle lengths were similar to their respective susceptible parents. The distributions of the segregating F_2 populations in the crosses imply that the trait is governed by more than one gene. The frequency distribution of the backcrosses skewed towards their respective recurrent parents.

SAMSORG17 had the highest panicle weight, with mean value of 118.09g, while ICSR94405 had the lowest with mean value of 76.43g. Mean value of F_1 hybrids in almost all the crosses were similar to the mid parental value, indicating preponderance of additive gene for this trait. The F_2 populations segregated outside their parental range, suggesting that the panicle weight genes are dispersed among the parents. BCP_1 and BCP_2 mean distribution skewed towards their respective recurrent parents.

The low mean grain yield values of the resistant varieties were not due to *Striga*effect, rather it was due to the poor agronomic qualities of the varieties. Most of the F_1 means were similar to their mid parental value, indicating preponderance of additive gene effect. The distributions of the segregating F_2 populations in all the crosses imply that grain yield is governed by more than one gene. Quantitative inheritance of grain yield has been reported by Showemimo*et al.*, (2005) in the study of genetics of sorghum cultivars under *Striga*infestation. BCP_1 and BCP_2 frequency distribution skewed towards their respective recurrent parents.

SAMSORG17 had the highest 1000 grain weight while ICSR94405 had the lowest. Most of the F_1 means were similar to the mid parental value, indicating predominance of additive gene effect. The distributions of the segregating F_2 populations in the crosses imply that the trait is governed by more than one gene. The backcrosses mean distribution skewed towards their respective recurrent parents.

The donor parents; ICSR94405 and ICSR94407 were truly *Striga*resistance with mean *Striga*count value of 0.03 and 0.00, respectively. Only one *Striga*emerged on ICSR94405, while on ICSR94407 there was no *Striga*emergence. Also the other three parents (SAMSORG14, SAMSORG17 and SAMSORG40) were susceptible with SAMSORG40 having the highest *Striga*emergence with mean *Striga*count value of 4.53, followed by SAMSORG14 with mean value of 3.13 while SAMSORG17 had fewer *Striga*emergence with mean value of 1.13. The fewer *Striga*emergences observed in SAMSORG17 conforms to result of Showemimo (2005) that SAMSORG17 is a promising genotype with some level of *Striga*resistance. There were few *Striga*emergences on the F_1 plants from the six crosses. This was in agreement with result from similar investigations with other sorghum genotypes (Vogler*et al.*, 1996; Haussmann *et al.*, 2000a).

For the F_2 and backcrosses, *Striga*emerged on some plants while some plants had no *Striga*.

Chi-square Values at Expected Segregation Ratios.

In the present study, plants with score of 0 to 4 were considered resistant, while plants with scores of 5 to 9 were considered susceptible (Sinebo and Drennan 2001). From the result, resistant parents common in different crosses showed consistency in reaction to *Striga*resistance in their F_1. The hybrids for all combinations were resistant with the mean damage score near that of the resistant parent, thus indicating that one or more dominant gene(s) which are complimentary controlled the resistance. In the F_2 population the chi-square values at expected segregation ratio 3:1 (resistant: susceptible) are significant in all the crosses, indicating poor fit of the observed segregation ratios. The expected ratio 9:7 is significant in the F_2 of three crosses, indicating poor fit of the observed segregating ratio, while it is non-significant in SAMSORG14 x ICSR94407, SAMSORG17 x ICSR94407 and SAMSORG40 x ICSR94407, indicating good fit of the observed segregating ratio. The 9:7 indicate complementary gene action or duplicate recessive epistasis where recessive alleles at either of two loci mask the expression of dominant alleles at both loci. This is in agreement with the result of (Ejeta et al., 2001). Similarly, significant chi-square values were obtained in three crosses at the expected segregation ratio 13:3, indicating poor fit of the observed segregation ratio. While three crosses where not significant, therefore indicating good fit of the observed segregation ratio. Three F_2 populations gave the best fit of 9:7 and the other three populations gave the best fit of 13:3 ratios. While those F_2 populations that fit into13:3 revealed that resistance is controlled by inhibitory gene interaction where a dominant article at one locus mask the expression of both dominant and recessive alleles at the second locus.Similar to result of Obilana, A.T. (1984). The BCP_1 populations gave the best fit of 3:1 backcross ratio, while BCP_2 fitted into 1:1 ratio.

CONCLUSION

From the study, Analysis of variance revealed highly significant difference among the genotypes for all the traits studied. It was confirmed that the two male parents (ICSR94405 and ICSR94407) were truly resistant, though their mean grain yield, plant height, panicle weight, panicle length and 1000 grain weight values were not the highest, due to their poor agronomic qualities when compared to the female parents, but the *Striga* damage score and *Striga* count which are the major resistance criteria, prove them to be resistant to *Strigahermonthica*. From the experiment, SAMSORG17 showed some level of tolerance because it recorded the lowest mean value for *Striga* count and *Striga* damage score among the IAR varieties.

Chi-square test revealed that none of the F_2 populations fitted into 3:1 (resistance: susceptible) segregation ratio, suggesting that resistance is not controlled by one dominant gene, three crosses fit into 9:7 ratio, suggesting that two dominant genes which are complimentary are in control and three crosses fit into 13:3 segregation ratio, revealing that resistance is controlled in part by gene at two or more loci.

In conclution,the study revealed that *Striga*resistance in sorghum is controlled by a few genes (oligogenic). Thus oligogenic inheritance of pest resistance genes is generally assumed to be more stable than monogenic resistance. All the traits are quantitatively heritable, thus repeatability of result and traits can be easily improved on.

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